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A narrow band audio spectrometer

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Research Department, Engineering Division
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A NARROW BAND AUDIO SPECTROMETER

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A NARROW BAND AUDIO SPECTROMETER

SUMMARY

This report describes a narrow-band spectrometer primarily intended to investigate speech colourations in small studios; a readily-portable version would be a useful instrument for many other investigations.

1. INTRODUCTION

Much attention has been devoted in the past to studies of the colourations which mar speech from small talks studios, but no satisfactory objective method has been found of measuring them, although the pulsed-glide technique[1] has provided valuable information. The conclusion reached from previous investigations is that the essential feature of a colouration is the transference, during the reverberation process, of energy from speech frequencies to a few strong room-modes; the bandwidth of the modes concerned is typically between 5 and 10 Hz and hence strong colourations are often observed if adjacent modes are separated by 20 Hz or more.

It follows, therefore, that if the spectrum of a syllable of speech in a reverberant room were analysed into a series of bands of 10 Hz width, colouration frequencies would appear as peaks in the spectrum. These peaks might be directly observable on a cathode-ray tube display, or detected by comparing the spectrum of speech recorded in a free-field room with that of a recording of the same speech played into the studio under investigation.

Audio-frequency spectrometers have been described by several authors[2,3] but in all these cases the bandwidths into which the spectrum is divided is very much greater than 10 Hz and would not be suitable.

Since every syllable has a different spectrum the apparatus should perform a complete analysis during the course of a single syllable, say in 0·15 sec.[4] Colourations of frequencies less than 80 Hz are seldom observed, as there is little energy in speech below that frequency, and those above 300 Hz are uncommon except in studios where the absorbing materials are very badly distributed. It was therefore necessary to use 22 filters to cover a bandwidth of 220 Hz in 10 Hz intervals.

If a common filter circuit with switched tuning elements were used, the response time of the filter at each frequency could not exceed 0·15/22 sec, i.e. 0·0068 sec. However, sampling of such short duration imposes a large uncertainty on the measurement of frequency, the bandwidth of a train of complete sinusoidal waves being inversly proportional to the number of cycles in the train. For a bandwidth of 10 Hz within the frequency range 80 — 300 Hz a sampling time of approx. 0·09 seconds is necessary. This is very much greater than the 0·0068 secs. resulting from switched operation.

To achieve satisfactory spectrum analysis, therefore, it is necessary to have a set of complete and independent filters, with a common input to which the speech is fed continuously, the filter outputs being sampled in sequence.

2. CONSTRUCTION OF THE SPECTROMETER

2.1. General Arrangement

Fig. 1 is a block schematic diagram of the whole apparatus. The filter-bank consists of 22 sections each of 10 Hz bandwidth, the lowest extending from 80 to 90 Hz and the highest from 290 to 300 Hz; their inputs are fed in parallel from a common input amplifier. The filter outputs are rectified and the resulting envelope outputs scanned by an electronic switch, the output of which is displayed by a suitable oscilloscope.

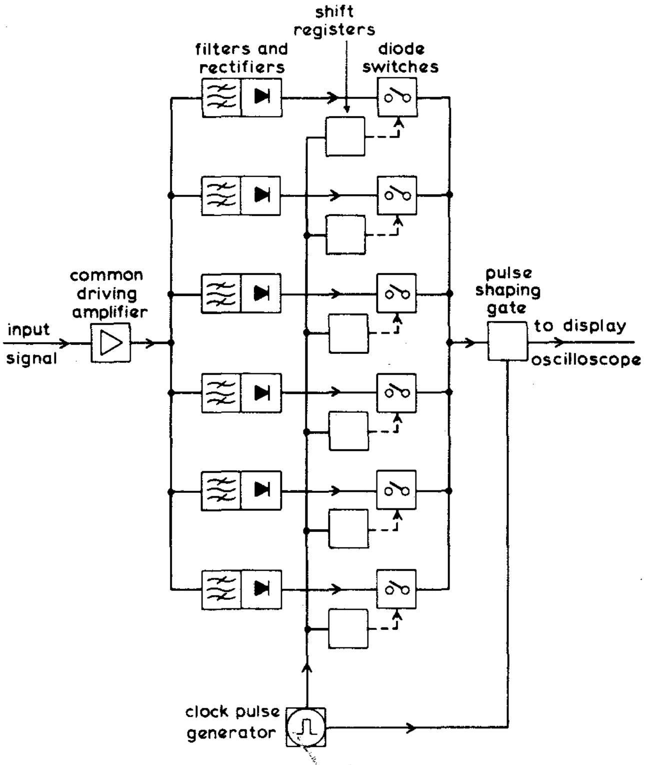

Fig. 1 - Block diagram of complete instrument

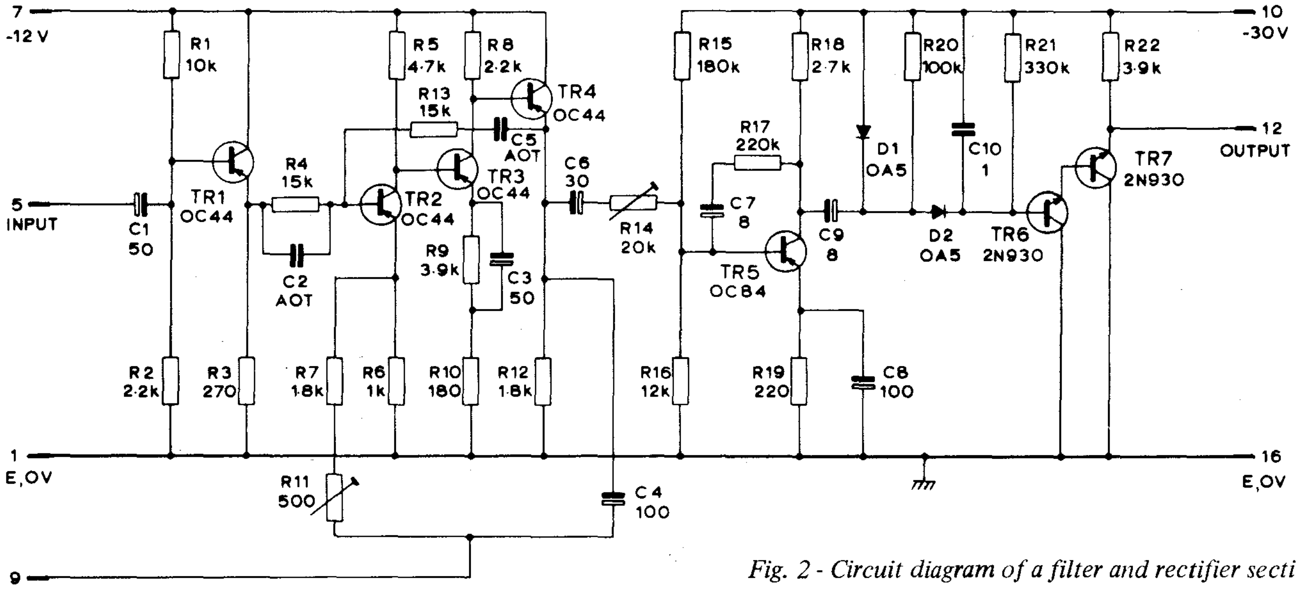

Fig. 2 - Circuit diagram of a filter and rectifier section

2.2. The Filter Sections

The filter configuration chosen consists of a Wien bridge circuit, using the RC elements R4, C2, R13 and C5 incorporated in the complete frequency-selective amplifier and rectifier unit shown in Fig. 2.

LC networks would have provided a better ultimate rejection but size and weight considerations dictated the use of the RC form used. The amplifier/rectifier units are constructed on individual printed-circuit cards, as shown in Fig. 3. In each unit the frequency selective network is followed by a rectification circuit having a time constant of approximately syllabic length, i.e. 0·2 secs.

Fig. 4 shows the overall characteristic of a typical unit. The effective bandwidth is 10 Hz between 3 dB points and the ultimate rejection is better than 30 dB; the attenuation between octave points is 20 dB. This selectivity was considered adequate for the investigations for which the instrument was designed.

2.3. The Sampling and Display Equipment

The envelope outputs of the individual units are sampled in sequence and the resultant signal displayed by an oscilloscope, as shown in Fig. 5; the filter frequencies increase from left to right along the horizontal axis and the vertical axis is directly related to amplitude.

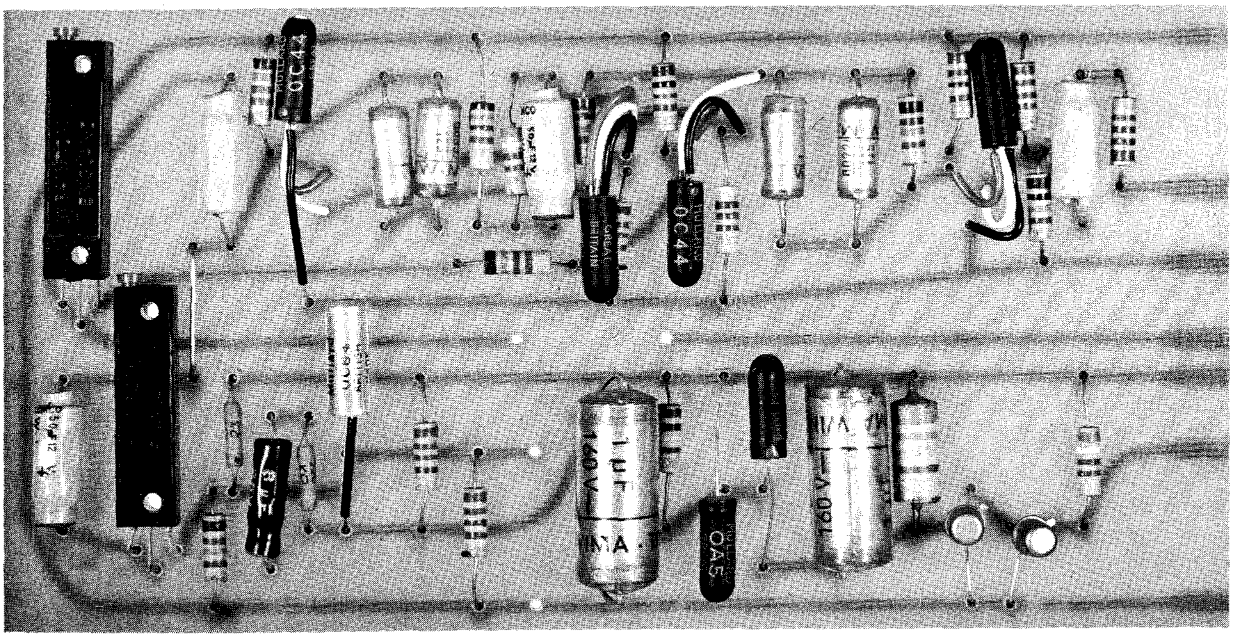

Fig. 3 - Layout of a filter and rectifier section printed circuit

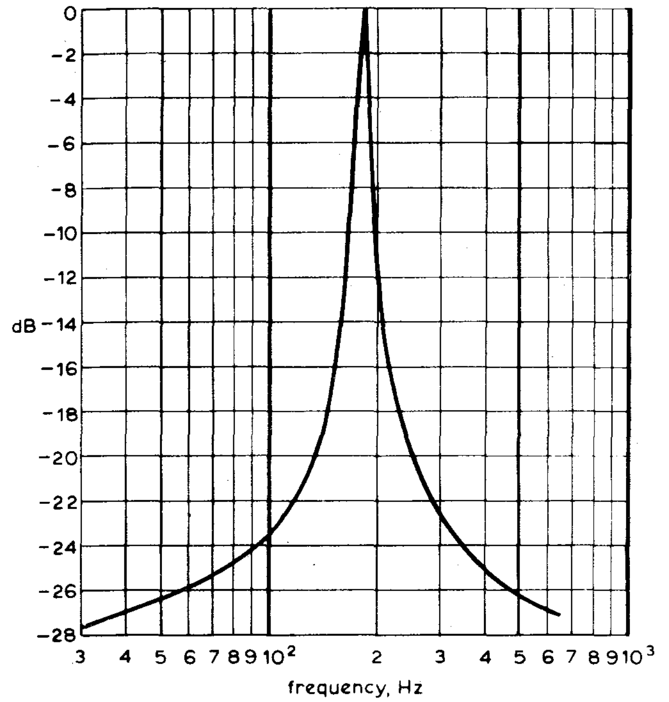

Fig. 4 - Overall response/frequency characteristic of 180 Hz filter and rectifier

In the electronic sampling system finally used each amplifier/rectifier unit is followed by a diode gate whose 'ON' or 'OFF' condition is determined by one section of a 22-section shift register. Only one section can be maintained in the 'ON' condition at any time, and this 'ON' condition is transferred from one section to the next on receipt of a clock pulse fed simultaneously to all sections. Thus the diode gates are opened and closed sequentially and the filter outputs sampled in turn. The sampling rate is, of course, dependent on the clock pulse rate and provision is made to vary this as required.

3. POTENTIAL USES

The equipment was designed as previously mentioned, for the study of the modifications introduced into speech spectra by the room modes in small studios. However, it would also prove useful for the examination of the low-frequency narrow-band components in machinery noise, such as that from ventilation systems; for that purpose it would be desirable to build the equipment into a self-contained portable unit containing a display tube and power supplies.

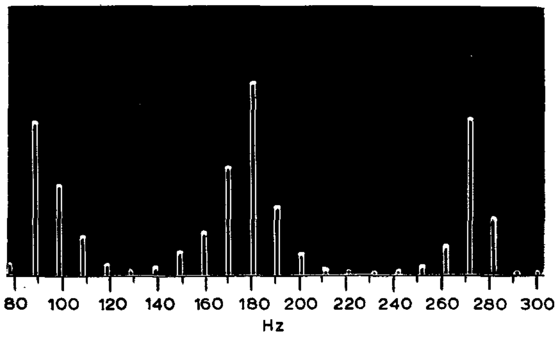

Fig. 5 - Spectrogram of phonetic syllable 'ɔ'

4. CONCLUSIONS

The experimental spectrometer has shown that it is possible to display the fine structure of speech spectra at syllabic rate, and the equipment could be used in other investigations for which no alternative is at present available.

5. REFERENCES

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